MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A
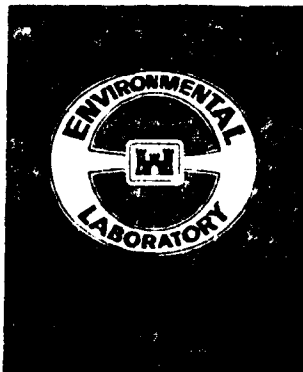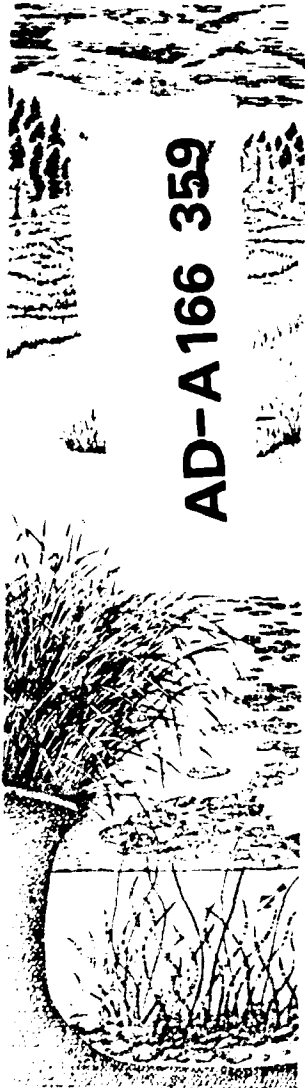
A CONCEPT AND PROCEDURE FOR DEVELOPING AND UTILIZING VEGETATION FLOOD TOLERANCE INDICES IN WETLAND DELINEATION

by

Russell F. Theriot, Dana R. Sanders, Sr.

Environmental Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631, Vicksburg, Mississippi 39180-0631

DTIC
ELECTE
APR 9 1986

B

February 1986
Final Report

DTIC FILE COPY

86 4 9 032

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Technical Report Y-86-1	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A CONCEPT AND PROCEDURE FOR DEVELOPING AND UTILIZING VEGETATION FLOOD TOLERANCE INDICES IN WETLAND DELINEATION		5. TYPE OF REPORT & PERIOD COVERED Final report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Russell F. Theriot Dana R. Sanders, Sr.		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Engineer Waterways Experiment Station Environmental Laboratory PO Box 631, Vicksburg, Mississippi 39180-0631		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Wetlands Research Program
11. CONTROLLING OFFICE NAME AND ADDRESS DEPARTMENT OF THE ARMY US Army Corps of Engineers Washington, DC 20314-1000		12. REPORT DATE February 1986
		13. NUMBER OF PAGES 25
14. MONITORING AGENCY NAME & ADDRESS(If different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Available from National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Adaptive mechanisms	Evapotranspiration	Saturation
Community	FTI numbers	Soil permeability
Delineation	Hydrologic zones	Wetlands
Ecological amplitude	Inundation	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes a concept and procedure which, when completed, may provide a method for wetland delineation. The primary objective of the research is to develop methods for calculating, verifying, and applying Flood Tolerance Index (FTI) numbers. These numbers would reflect a quantitative estimate of the hydrology of an area using vegetation as an indicator and would greatly strengthen the multiple parameter approach to wetland delineation by defining the frequency and duration of the hydrologic events.

(Continued)

DD FORM 1473 EDITION OF 1 NOV 65 IS OBSOLETE

20. ABSTRACT (Continued).

CONT

It will also allow greater flexibility by dividing the wetlands into discrete zones. This could be invaluable for delineating and for assessing wetlands functions and values for regulatory or mitigation actions.

PREFACE

This report was sponsored by the Department of the Army, Office of the Chief of Engineers (OCE), Directorate of Civil Works (DAEN-CW), through the US Army Corps of Engineers Wetlands Research Program (WRP). The WRP is managed by the US Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss. Technical Monitors for OCE during the preparation of this report were Drs. John R. Hall and Robert J. Pierce and Mr. Phillip C. Pierce.

Authors of this report were Mr. Russell F. Theriot and Dr. Dana R. Sanders, Sr., both of the Wetlands and Terrestrial Habitat Group (WTHG), Environmental Resources Division (ERD), Environmental Laboratory (EL). Dr. Dan K. Evans, Marshall University, Huntington, W. Va., provided technical review of methods to collect vegetation data. MAJ Jeffrey Irvin, US Military Academy, West Point, computerized the technique for analyzing hydrologic data. Dr. Sanders served as Leader, Wetlands Research Team, WTHG, during the final review and publication of the report. The study was conducted under the direct supervision of Dr. Hanley K. Smith, Chief, WTHG, and the general supervision of Dr. C. J. Kirby, Jr., Chief, ERD, and Dr. John Harrison, Chief, EL. Dr. Smith was Manager of the WRP.

Director of WES was COL Allen F. Grum, USA. Technical Director was Dr. Robert W. Whalin.

Accession For		
NTIS GRA&I	☑	
DTIC TAB	☐	
Unannounced	☐	
Justification		
By		
Distribution/		
Availability Codes		
	Avail and/or	
Dist	Special	
A-1		

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC)
UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
acres	0.4047	hectares
cubic feet	0.0283	cubic metres
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*
feet	0.3048	metres
inches	2.54	centimetres
miles (US statute)	1.6093	kilometres
square inches	6.4516	square centimetres
yards	0.9144	metres

---

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

A CONCEPT AND PROCEDURE FOR DEVELOPING AND UTILIZING VEGETATION FLOOD TOLERANCE INDICES IN WETLAND DELINEATION

PART I: INTRODUCTION

Background

1. The concept described in this report serves as the basis of a technique for using plant community structure to estimate the hydrology of an area. Each plant species has a specific ecological amplitude with respect to any environmental factor that constitutes a gradient. The degree of wetness (i.e., hydrology gradient) is widely recognized as the principal determinant of species composition of wetland plant communities. The technical literature reveals a definite relationship between plant species distribution and the frequency and duration of inundation/soil saturation. The numerical expression (Flood Tolerance Index (FTI) number) of this vegetation/hydrology relationship should enable estimation of the degree of wetness (i.e., hydrology) of an area based on vegetation. Application of the FTI concept will provide valuable information for consideration in making wetland determinations, since site-specific hydrologic data are usually lacking.

Purpose and Objectives

2. The purpose of this report is to describe a concept and methods for determining FTI numbers for plant species occurring in nontidally influenced areas subjected to backwater or overbank flooding.

3. Objectives of this research were to:

   <u>a</u>. Develop methods for determining hydrologic zone elevations for a particular wetland type.

   <u>b</u>. Develop methods for characterizing vegetation in various hydrologic zones.

   <u>c</u>. Develop methods for calculating, verifying, and applying FTI numbers.

4

PART II: RATIONALE

4. Studies describing the relationship between plant species distribution and specific inundation/saturation regimes are relatively rare (Bedinger 1971, 1978; Hosner and Boyce 1962; Huffman 1980; Dickson, Hosner, and Hosley 1965; Hodges and Switzer 1979; and Larson et al. 1980). However, most have concluded that frequency and duration of inundation/saturation exert a controlling influence on the composition, structure, and distribution of wetland plant communities.

5. The hydrologic gradient in wetlands ranges from nearly continuous inundation/saturation in deep swamps to infrequent inundation/saturation events for brief periods at higher elevations. Several discrete plant communities (species associations) may occur along this hydrologic gradient. Tolerance to inundation/saturation varies both among and within species, and the degree of tolerance is critical to species distribution. Species with the greatest inundation/saturation tolerance occur on low, wet sites, while the least tolerant species occur on upland sites. Because different species respond to different timing and duration of inundation, a strong correlation may exist between the distribution of a species and its associated hydrologic and soil-moisture conditions (Bedinger 1971 and 1978; Hosner and Boyce 1962; Huffman 1980; Dickson, Hosner, and Hosley 1965; Hodges and Switzer 1979; and Larson et al. 1980). For example, Bedinger (1971) found a definite relationship between the occurrence of species and the frequency and duration of inundation in the lower White River Valley, Ark.

6. Plant species that tolerate different degrees of inundation/saturation share some common adaptive mechanisms for occurrence in wetlands. These adaptive mechanisms have been generally characterized as either morphological or physiological. Morphological adaptations include buttressed tree trunks, pneumatophores, hypertrophied lenticils, adventitious roots, shallow root systems, polymorphic leaves; and inflated leaves, stems, or roots. Physiological adaptations usually involve the ability of roots of flood-tolerant species to accelerate the rate of anaerobic respiration, oxidize the rhizosphere, and tolerate high concentrations of carbon dioxide (Hook and Brown 1973). Other examples of physiological adaptations include the ability for root growth in low oxygen tensions, increased levels of nitrate reductase, absence of alcohol dehydrogenase activity, and the ability to concentrate malate, a nontoxic

5

by-product of anaerobic respiration, in the root system (Hook and Brown 1973, Hook and Scholtens 1978, Vester 1972). Although all morphological adaptations have a physiological effect, some physiological adaptations are not expressed by obvious morphological characteristics.

7. Species having adaptations for occurrence in wetlands may occur in a range of wetland hydrologic conditions; however, each species has its unique ecological amplitude (Figure 1). Species having similar ecological amplitudes often occur as species associations in areas of similar hydrologic conditions. If various wetland hydrologic zones can be characterized and their locations in field sites can be determined, then the characterization of vegetation by hydrologic zone and subsequent analysis of data should lead to a numerical expression (FTI number) that describes species occurrence in relation to the hydrologic gradient. Once the FTI numbers have been determined, vegetation can be used to estimate the hydrologic zone of a site.
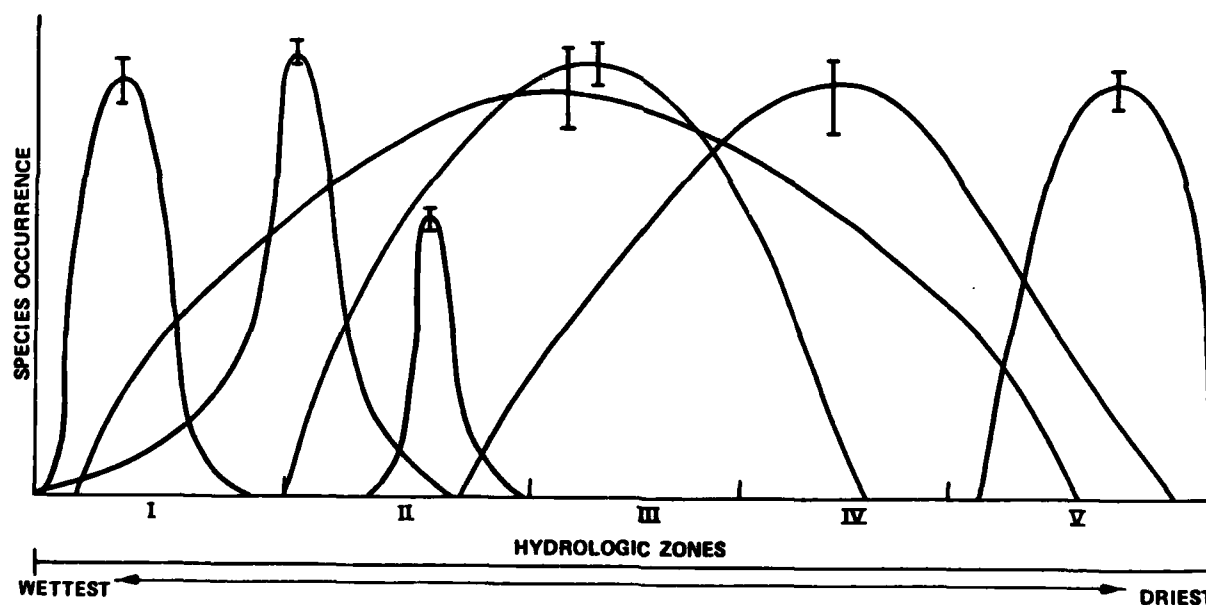

Figure 1. Hypothetical depiction of the ecological amplitude of species along the hydrologic gradient. FTI values represent the average position of a species along the gradient. Roman numerals represent different hydrologic zones, with I being the wettest and V being the driest. The brackets represent theoretical standard deviations of the mean

PART III: APPROACH

8. The concept of correlations of plant species associations with duration of inundation/soil saturation should apply and be testable in any wetland type for which adequate hydrologic data are available. However, this concept can be tested more readily in areas that are seasonally inundated and for which stream gage data are available. Areas (e.g., potholes, seeps, and bogs) for which adequate hydrologic data are not normally available, do not readily lend themselves to such efforts. Other wetland types, such as coastal marshes subject to tidal influence, accretion, and subsidence, and arctic tundra that remains frozen for long periods, pose special problems that must be addressed to define their hydrologic regimes. This report considers only areas subject to backwater or overbank flooding in Palustrine Forests of the southeastern United States.

9. The basic approach of this study was to use stream gage data, soil permeability coefficients, and evapotranspiration rates to determine frequency and duration of inundation and soil saturation for hydrologic zones. Since inundated or saturated soil conditions act as a selective agent primarily during the growing season and have little or no effect on dormant populations (Sigafoos 1964), stream gage data for only the growing-season period should be used to define hydrologic zones. Growing season is defined as the period between the last freeze (0° C) in the spring and the first freeze in the fall. This information can be obtained from Soil Conservation Service (SCS) county soil surveys. Based on previous work (Larson et al. 1980), the hydrologic gradient has been divided into six hydrologic zones. Since Zone I is an open-water (aquatic) habitat, it is not considered to be a wetland zone and was excluded from this study. Definitions of hydrologic zones II through VI are presented in Table 1. Zone II is the wettest forested zone and Zone VI (non-wetland) is the driest. By using hydrology and soil permeability data to delineate these hydrologic zones in a number of locations within a geographical area, it should then be possible to characterize the plant species in each hydrologic zone by applying standard ecological sampling methods. The resulting values can then be used to calculate an FTI number for each plant species for which data are obtained.

7

Table 1

Hydrologic Zones Occurring in Palustrine Forests of the

Southeastern United States

Zone	Name	Duration*
II	Semipermanently to permanently inundated or saturated	>75%-100%
III	Regularly inundated or saturated	>25%-75%
IV	Seasonally inundated or saturated	>12.5%-25%
V	Irregularly inundated or saturated	≥5%-12.5%
VI	Intermittently inundated or saturated	<5%

* Duration is analyzed using streamflow data for only the growing-season period.

PART IV: METHODS

Selecting Study Sites

10. Several criteria must be considered when selecting study sites.
First, the wetland type (e.g., Palustrine Emergent, Palustrine Forested, etc.)
should be defined. This selection will ensure the continuity of hydrologic
data and wetland species that will be encountered. The study should encompass
the largest possible area within the same ecological and floristic region.
This will ensure maximum utility of the data during analysis, aid in locating
sufficient suitable study sites, and significantly reduce the degree of cli-
matic variation on species composition. Other criteria for site selection
should include the following:

    a. Sites free from major disturbance (e.g., recent timber harvest-
       ing, ditching, diking, etc.).

    b. Availability of sufficient hydrologic data (approximately
       20 years of daily stream gage readings).

    c. Stream gage data that accurately portray water-level fluctu-
       ations on the site (consider ponding, tributary influence
       between site and gage, etc.).

    d. No anticipated changes in study sites during the study period
       (e.g., timber harvesting, ditching, etc.).

    e. Availability of soils data (e.g., soil maps, soil type, texture,
       and permeability coefficients).

    f. Plant communities characteristic of the area.

As many sites as possible should be included in the study, but a minimum of
10 sites representative of the area are recommended.

11. Adequate hydrologic data may not be available for many wetland types
(e.g., bogs, seeps, wet savannas, etc.). In such cases, this concept can only
be applied if long-term hydrologic studies are conducted to obtain the informa-
tion required to define hydrologic zones.

Determining Hydrologic Zone Elevations

12. To determine hydrologic zone elevations for individual sites, site-
specific hydrologic data must be used. Data may be obtained in the form of
staff gage readings, flow data, and/or ground-water (piezometer) data.
Different types of hydrologic data for specific wetland types may require

9

different analyses to satisfy hydrologic zone definitions. Regardless, a large amount of data analysis is involved, which can best be handled by computer processing.

13. A computer program was developed by the US Army Engineer Waterways Experiment Station (WES) for determining hydrologic zone elevations in study sites where backwater flooding occurs. The program analyzes either daily flow (discharge) or daily stage data, but it could be modified for analysis of other types of hydrologic data.

14. The output of the program (flow or stage data) corresponds to the duration of inundation plus saturation, as defined for each hydrologic zone boundary (Table 1). For example, a stage of 16.8 ft* for Zone II of a site would reflect the highest stage where the soil has been inundated and saturated at least 75 percent of the growing season on the average for the period of record used in the study.

15. Hydrologic zone elevations for a site are computed in the following manner. The most recent 20 years of daily stream gage data for the site must be obtained from either the USGS** as flow data or from the local CE district as stage or flow data. These data are then analyzed using the computer program. If the gage data are daily discharges, then a rating (relationship between stage and discharge) must be obtained to determine the corresponding stages. The gage datum is then added to the stage for each zone to obtain the mean sea level elevations at the gage. If the site is not adjacent to the gaging station, the change in water-surface elevation between the study area and the gaging station must be determined. This can be accomplished by using a slope correction or, if necessary, cross-sectional surveys of the stream between the gaging station and study site. A method for backwater calculation (HEC-2) can then be used to compute a water-surface slope between the gage and the study site. A hydrologist should be consulted to determine the best method to use. These adjustments, which are site specific, are applied manually to the computer-generated hydrologic zone values.

16. The dates of the first and last day of the growing season for each site must be provided as input to the computer program. The program reads all of the data between these two dates, eliminates all nongrowing season data, and

---

* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

** USGS Water Resources Division, 437 National Center, 12201 Sunrise Valley Drive, Reston, Va. 22092

ranks the remaining daily readings (during the 20-year period of record) from
highest flow (or stage) to lowest. It then computes elevations corresponding
to the 75-, 25-, 12.5-, and 5-percent durations of inundation as defined for
each hydrologic zone. However, the resulting elevations are based only on in-
undation and do not include the period during which the soils remain saturated
after a period of inundation. To integrate saturation effects, a general de-
scription of soil types occurring in the study site must be obtained from the
Soil Conservation Service (SCS) soil surveys. During a reconnaissance of the
area, soil samples should be taken and the soil texture in each zone should be
determined. An estimated range of permeabilities for the top 12 in. of soil
(effective root zone) can then be determined. This range will approximate the
period required for the root zone to become saturated, once inundated. The
lowest permeability value determined from the soil samples should be used to
determine the minimum duration of inundation required to saturate the soil.
Another estimated range of permeabilities of the soil between the 12-in. and
3-ft depths must be determined. The lowest permeability value in this range
should be used to provide an estimate of the time required for the root zone
to become desaturated after the water recedes. An evapotranspiration factor
has also been incorporated into the computer program, since the depth to the
water table could be affected through water loss due to evapotranspiration.

17. Permeability and evapotranspiration coefficients are then provided
as input into the program, and new flow (or stage) values for hydrologic zones
are derived reflecting both inundation and saturation. Determining these new
values is an iterative process, requiring search by the computer. The computer
program will then add the days of saturation to the days of inundation, and the
output will be flow (or stage) values that represent the estimated boundary of
each hydrologic zone, based on inundation and saturation. The computer program
counts saturation days using the logic displayed in Figure 2.

Surveying Hydrologic Zone Elevations

18. A temporary benchmark must be established at each site by surveying
from a permanent benchmark. Mean sea level elevations for each hydrologic zone
boundary must then be surveyed along the topographic gradient. Contours for
each hydrologic zone boundary within the site should be marked with surveyor
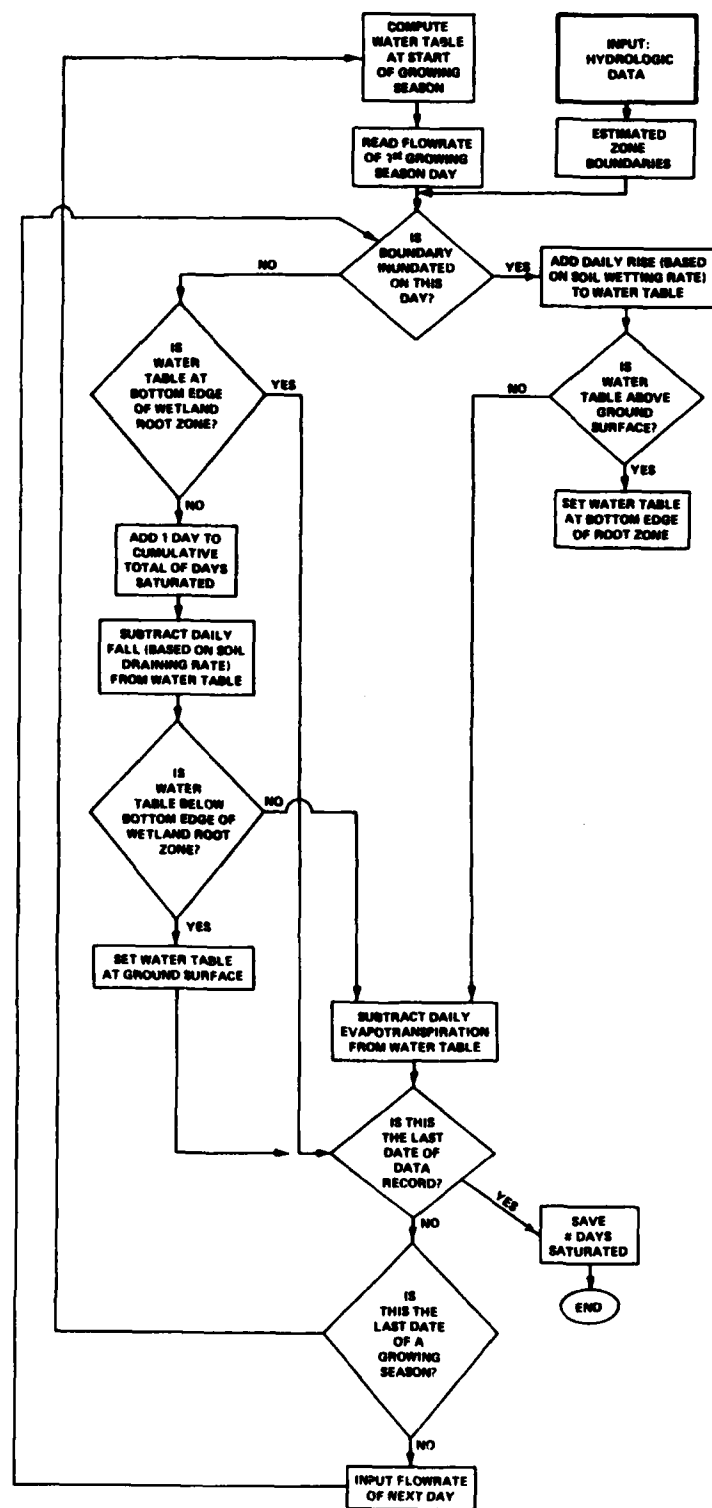flags. Figure 3 shows a schematic profile of a study site.

11

Figure 2. Logic for calculating the number of saturation days
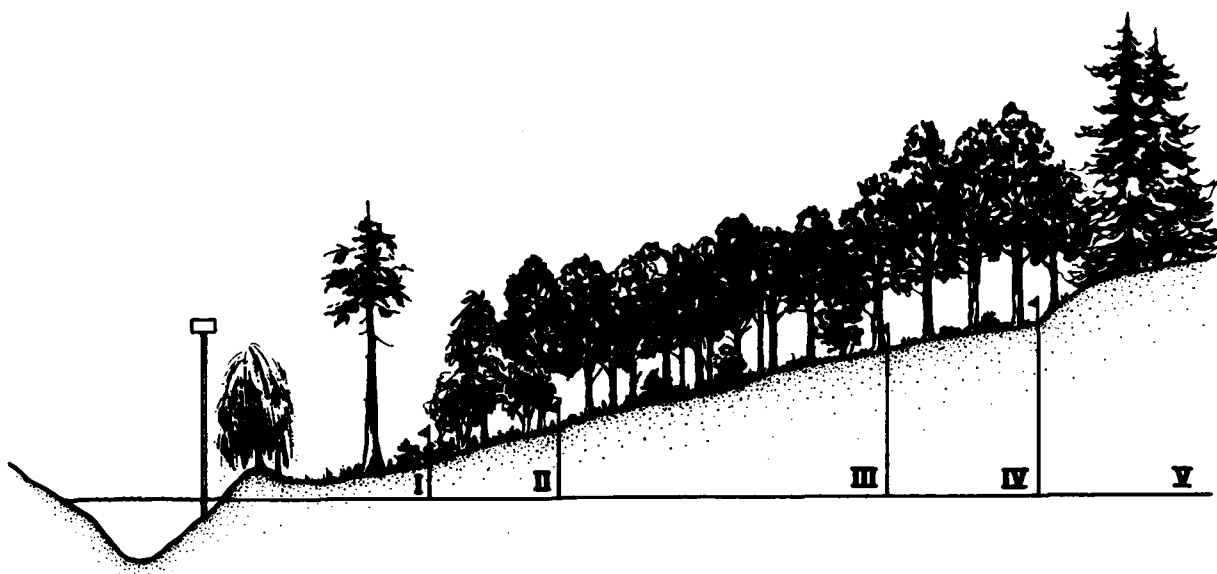
Figure 3.   Schematic profile of a study site

Selecting Sample Plot Location and Size

19.   Sample plots must be established parallel to the hydrologic zone
boundary.   Plots should be positioned on the downslope side of the boundary
with a 5-m-wide buffer zone maintained between the sample plots and the upper
boundary of the hydrologic zone.   Ten 80-m^2 sample plots (total sample area of
800 m^2) should be sampled.   Hydrologic zones wider than 40 m should be divided
into upper and lower subzones along the long axis.   A belt transect (10 m wide
by 160 m long) containing 10 sample plots (8 m by 10 m) should be established
in each subzone, and five 10- by 8-m sample plots from each transect should
be randomly selected for sampling trees, saplings/shrubs, and lianas (woody
vines).   Two 1-m^2 quadrats randomly selected in each subplot should be used
for sampling herbaceous vegetation.   For hydrologic zones less than 40 m wide,
vegetation should be sampled in 10 randomly chosen, 8- by 10-m plots from a
single belt transect (10 m wide and 160 m long).   Plot dimensions may vary in
extremely narrow hydrologic zones, but the number of sample plots must always
be 10 and the area of each sample plot must be 80 m^2.   Surveyed zones that are
too narrow to allow maintenance of the 5-m buffer zone between the sample
plots and upper limit of the zone boundary should not be sampled.

13

20. The following procedures should be used for sampling the vegetation in each hydrologic zone.

Trees

21. Identify all trees in each sample plot to species, and measure and record (Figure 4) the diameter of each tree (individuals having a diameter of ≥7.5 cm at breast height (1.5 m)), exclusive of woody vines. Record diameters to the nearest whole centimeter.

Saplings and shrubs

22. Identify all saplings and shrubs (woody plants <7.5 cm in diameter, but ≥1.0 m in height, excluding vines) in each plot to species, count the stems of each species, and record the height class of each individual. Saplings or shrubs with more than one stem clustered from a single root system are counted as individuals only when separation occurs at or below ground level. Use the following height classes:

Height Class	Class Range, m	Midpoint of Class Range, m
1	1.0-2.0	1.5
2	2.1-3.0	2.5
3	3.1-4.0	3.5
4	4.1-5.0	4.4
5	>5.0	5.5

Lianas

23. Identify lianas (climbing woody vines, >1.0 m in height) in each plot to species, count the stems of each species, and record the height class of the highest individual on each tree or sapling/shrub. Use the following height classes:

Height Class	Class Range, m	Midpoint of Class Range, m
1	1.0-3.0	2.0
2	3.1-6.0	4.5
3	6.1-12.0	9.0
4	>12.0	15.0

Figure 4. Sample field-data form

15

Record lianas when any portion of the plant occurs in, or overhangs, the plot. Record individual stems when separation from the root system occurs at or below ground level.

Herbs and woody seedlings

24. Estimate percent cover for each species of herb and woody seedling (<1.0 m in height) in two randomly located 1.0-m^2 quadrats in each subplot. Use Daubenmire's cover class method (Daubenmire 1968) as follows:

Cover Class	Class Range, %	Midpoint of Class Range, %
1	≤5.0	2.5
2	5.1-25.0	15.5
3	25.1-50.0	38.0
4	50.1-75.0	63.0
5	75.1-95.0	85.5
6	>95.0	98.0

Analyzing Vegetation Data

25. Species importance values* are used to determine the FTI number for each species. Importance values for species in all vegetation layers except the herbaceous layer are calculated by adding values for relative density, relative frequency, and relative dominance. Importance values for herbaceous species are calculated by summing relative frequency and relative dominance. Formulae for analyzing vegetation data are provided in the following paragraphs.

Trees

26. The following formulae are used in calculating importance values for a tree species (SpA):

$$\text{Frequency, } \% = \frac{\text{number of plots with SpA}}{10} \times 100$$

$$\text{Relative frequency, } \% = \frac{\text{frequency of SpA}}{\text{total frequency for all species}} \times 100$$

---

* A quantitative term describing the relative influence of a plant species in a plant community. This is normally the sum of relative frequency, relative dominance, and/or relative density.

16

$$\text{Relative density, \% } = \frac{\text{number of individuals of SpA}}{\text{total number of individuals of all species}} \times 100$$

$$\text{Relative dominance, \% } = \frac{\text{total basal area of SpA}}{\text{total basal area of all species}} \times 100$$

Importance value of SpA = relative frequency (SpA) + relative density (SpA) + relative dominance (SpA)

Saplings and shrubs

27. Frequency, relative frequency, and relative density are computed as for trees (paragraph 26). Height classes are used to determine relative dominance, and midpoints of height classes ranges are used for calculations.

$$\text{Relative dominance, \% } = \frac{\text{total midpoints of class ranges for SpA}}{\text{total midpoints of class ranges for all species}} \times 100$$

Importance value of SpA = relative frequency (SpA) + relative density (SpA) + relative dominance (SpA)

Lianas

28. Frequency, relative frequency, and relative density are calculated as for trees. Relative dominance is calculated (as for saplings) using the four height classes given in paragraph 23. Importance value for a species is calculated by summing relative frequency, relative density, and relative dominance.

Herbs and woody seedlings

29. The following formulae are used for computing importance values of herbs and woody seedlings:

$$\text{Frequency, \% } = \frac{\text{number of plots of occurrence of SpA}}{20} \times 100$$

$$\text{Relative frequency, \% } = \frac{\text{frequency of SpA}}{\text{total frequencies of all species}} \times 100$$

$$\text{Relative dominance, \% } = \frac{\text{total midpoints of cover class ranges for SpA}}{\text{total midpoints of cover class ranges for all species}} \times 100$$

17

Importance value of SpA = relative frequency (SpA)
+ relative dominance (SpA)

Calculating Species FTI Numbers

Methods

30. FTI numbers must be calculated for each species occurring in each vegetation layer: trees, saplings and shrubs, lianas, and herbs and woody seedlings. It is possible for a particular species to have three different FTI numbers, depending on its size or growth form. For example, *Quercus nigra* will have three different FTI numbers when it occurs as a tree, a sapling, and a seedling. Once importance values have been computed for each plant species in each vegetative layer of all hydrologic zones in all sites, the resulting importance values are used to compute species FTI numbers for each site by employing the following formula:

$$FTI_i = \frac{\Sigma_j (j \cdot IV_{ij})}{\Sigma_j IV_{ij}}$$

where

i = the ith species

j = 2,6 (hydrologic zones II-VI)

IV_{ij} = importance value for species i in the jth hydrologic zone

31. When species FTI numbers have been computed for all species in all sites, the average FTI number, denoted $\overline{FTI}$, for a species across all sites can be calculated using the following formula:

$$\overline{FTI}_i = \frac{\sum_{j=1}^{n_i} FTI_{ij}}{n_i}$$

18

where

$i = i^{th}$ species

n_i = number of sites at which species i occurred

FTI_{ij} = FTI value of species i at site j

Variance and standard deviation may then be computed using standard statistical methods.

Example calculation

32. After importance values have been calculated for all species at all sites, suppose that *Carya aquatica* trees occurred in 12 of 20 sites as shown in Table 2.

33. The FTI number for *C. aquatica* trees in site 3 is calculated as follows:

$$FTI_{13} = \frac{\sum_{j=2}^{6} IV (j \cdot IV_{ij})}{\sum_{j=2}^{6} IV_{ij}}$$

$$= \frac{(40.6 \times 3) + (5.1 \times 4)}{40.6 + 5.1}$$

$$= \frac{121.8 + 20.4}{45.7}$$

$$= \frac{142.2}{45.7}$$

$$= 3.11$$

34. FTI numbers for *C. aquatica* trees in the other sites are computed in the same manner and are shown in the right column of Table 2. The average FTI number, $\overline{FTI}$, for *C. aquatica* trees is calculated by summing FTI values across all sites where *C. aquatica* occurred and dividing by the number of sites where the species occurred. Using the formula:

19

Table 2
Importance Values of *Carya aquatica* trees by Hydrologic Zone at 20 Sites
Hydrologic Zone – Importance Values, %

Site	II	III	IV	V	VI	FTI
1	0.0	0.0	0.0	0.0	0.0	--
2	0.0	0.0	0.0	0.0	0.0	--
3	0.0	40.6	5.1	0.0	0.0	3.11
4	0.0	39.0	11.1	0.0	0.0	3.22
5	0.0	26.1	0.0	0.0	0.0	3.00
6	0.0	69.5	0.0	0.0	0.0	3.00
7	0.0	69.2	34.2	0.0	0.0	3.33
8	0.0	5.2	0.0	0.0	0.0	3.00
9	0.0	15.2	0.0	0.0	0.0	3.00
10	0.0	121.9	57.8	0.0	0.0	3.32
11	0.0	136.6	31.9	0.0	0.0	3.19
12	0.0	74.2	0.0	0.0	0.0	3.00
13	0.0	34.3	0.0	0.0	0.0	3.00
14	0.0	33.8	19.5	0.0	0.0	3.37
15	0.0	0.0	0.0	0.0	0.0	--
16	0.0	0.0	0.0	0.0	0.0	--
17	0.0	0.0	0.0	0.0	0.0	--
18	0.0	0.0	0.0	0.0	0.0	--
19	0.0	0.0	0.0	0.0	0.0	--
20	0.0	0.0	0.0	0.0	0.0	--

$$\overline{FTI}_i = \frac{\sum\limits_{j=1}^{n_i} FTI_{ij}}{n_i} = \frac{37.54}{12} = 3.13$$

35. Using standard analytical procedures, two standard deviations around, the mean equals 0.30. Thus the true $\overline{FTI}$ number for *C. aquatica* trees lies between 2.83 and 3.43 at the 0.05 probability level.

36. After $\overline{FTI}$ numbers have been calculated for each species in each vegetation layer, a list can be produced for each vegetation layer that presents the $\overline{FTI}$ for each species. For practical purposes, the lists should be alphabetized. Such a list will be provided for species occurring in bottomland hardwood forests of the southeastern United States upon completion of the current study.

PART V: VERIFICATION OF ASSIGNED FTI NUMBERS

37.   After FTI numbers have been obtained for plant species occurring in the wetland type, resulting species FTI numbers must be subjected to field verification.   The following procedure should be employed, essentially reversing the procedure used for determining species FTI numbers.

Site Selection

38.   Several study sites should be selected in the same wetland type used for calculating species FTI numbers.   Criteria for site selection should include:

    a. Some sites must be wetlands based on vegetation, soils, and hydrology, and at least one must be nonwetlands.

    b. Vegetation and hydrologic characteristics must be relatively uniform within each site.

    c. Sites must be located near stream gage stations that have been operational for at least the most recent 20 years.

Plant Data Collection

39.   All plant species present on each site should be recorded, and the five dominant species in each vegetative stratum should be determined.   In addition, a grid method should be used to collect quantitative data from each site.   Each point on the grid where the lines intersect constitutes a sampling point.   The same methods presented in paragraphs 21-24 should be used for sampling the various strata of vegetation, and the same quantitative values (importance values) presented in paragraphs 25-29 should be calculated for each species.

Calculation of Site FTI Numbers

40.   Site FTI numbers must be calculated for each site.   These will represent the hydrologic zone or zones for the site.   The site FTI value can be calculated in two ways:

<u>a</u>. <u>Species presence</u>. FTI numbers for all species (regardless of abundance) on a site will be summed and divided by the number of species. Only those species for which FTI numbers are available can be used in this calculation. This method gives equal weight to each species.

<u>b</u>. <u>Weighted FTI</u>. This method of calculating the site FTI number requires some measure of species prominence (e.g., importance value). The calculation will be as follows:

$$\text{Site FTI} = \frac{\Sigma \text{FTI}_i \cdot C_{i,n}}{\Sigma C_{i,n}}$$

where

FTI_i = flood tolerance index number for species i to n

i = species

$C_{i,n}$ = importance value for species i

Hydrologic Zone Determination

41. Using available hydrologic data, the hydrologic zone(s) for each site must be determined in the same manner as in the original study sites. Results of hydrologic zone determinations using vegetation must be compared to zone determinations based on hydrologic data. General agreement between the two systems will provide evidence that the concept of using vegetation to estimate hydrologic zones is valid and that FTI numbers can be used to make routine wetland determinations.

PART VI: APPLICATION OF FTI NUMBERS

42. The resulting verified list of FTI numbers for plant species may be used by CE district regulatory personnel to estimate the hydrology of an area. In evaluating an area for which a permit has been requested, the field inspector would subjectively estimate the five dominant plant species in the area, average the corresponding FTI numbers, and calculate a site FTI number. The following tabulation is an example in which only the tree layer was used for the determination:

Dominant Species	Calculated Species FTI Number
Swamp privet	2.98
Water hickory	3.13
Box elder	4.26
Overcup oak	3.21
Sugarberry	4.49
Total	18.07

$$\text{Site FTI number} = \frac{18.07}{5} = 3.61*$$

---

* Represents estimated hydrologic zone of the area.

43. The site FTI (3.61) indicates that the area is in hydrologic zone III, which by definition (Table 1) is inundated/saturated for at least 25 percent but not more than 75 percent of the growing season. Also, the area can be expected to be inundated at least every other year (on average).

44. Providing FTI numbers for trees, shrubs, saplings, seedlings, woody vines, and herbaceous species aids the field inspector in defining the wetlands boundary. The FTI system can be used to delimit all or any part of an area under consideration. This system can be easily incorporated into the multiple parameter approach of using vegetation, soils, and hydrology to delimit wetlands by simply adding information on the soils found onsite, since the vegetation FTI numbers also reflect area hydrology.

REFERENCES

Bedinger, M. S. 1971. "Forest Species as Indicators of Flooding in the Lower White River Valley, Arkansas," Geological Survey Research, US Geological Survey Professional Paper 750-C, pp C248-C253.

_____. 1978. "Relation Between Forest Species and Flooding," Wetland Functions and Values: The State of Our Understanding--Proceedings of the National Symposium on Wetlands, P. E. Greeson, J. R. Clark, and J. E. Clark, eds., American Water Resources Association, Minneapolis, Minn., pp 427-435.

Dickson, R. E., Hosner, J. F., and Hosley, N. W. 1965. "The Effects of Four Water Regimes upon the Growth of Four Bottomland Tree Species," Forest Science, Vol 11, pp 299-305.

Daubenmire, R. 1968. Plant Communities: A Textbook of Plant Synecology, Harper and Row Publishers, New York.

Hodges, J. D., and Switzer, G. L. 1979. "Some Aspects of the Ecology of Southern Bottomland Hardwoods," Jour. Paper No. 4087, Mississippi Agriculture and Forestry Experiment Station, pp 360-365.

Hook, D. D., and Brown, C. L. 1973. "Root Adaptations and Relative Flood Tolerance of Five Hardwood Species," Forest Science, Vol 19, pp 225-229.

Hook, D. D., and Scholtens, J. R. 1978. "Adaptations and Flood Tolerance of Tree Species," Plant Life in Anaerobic Environments, D. D. Hook and R. M. M. Crawford, eds., Ann Arbor Science Series, Inc., Ann Arbor, Mich., pp 299-331.

Hosner, J. F., and Boyce, S. G. 1962. "Tolerance to Water Saturated Soil of Various Bottomland Hardwoods," Forest Science, Vol 8, pp 180-186.

Huffman, R. T. 1980. "Bottomland Hardwood Forest Communities and Their Relation to Flooded and Saturated Soil Conditions," Miscellaneous Paper presented at the Bottomland Hardwood Wetlands Workshop, Lake Lanier, Ga., June 1-5, 1980.

Larson, J. S., Bedinger, M. S., Bryan, C. F., Brown, S., Huffman, R. T., Miller, E. L., Rhodes, D. G., and Touchet, B. A. 1980. "Transition from Wetlands to Uplands in Southeastern Bottomland Hardwood Forests," Workshop on Bottomland Hardwood Forest Wetlands on the Southeastern United States, Benforado and Clark, eds., Lake Lanier, Ga., pp 225-267.

Sigafoos, R. S. 1964. "Botanical Evidence of Floods and Flood-Plain Deposition," US Geological Survey Professional Paper 485-A, US Geological Survey, Washington, DC.

Vester, G. 1972. "A Metabolic Study of Flooding Tolerance in Trees," Ph. D. Thesis, University of Munich, Munich, West Germany.

END

DTIC

5-86